DEFENCE DÉFENSE

Thermal models of the human auditory canal

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Defence R&D Canada

Technical Report
DCIEM TR 2001-016
February 2001

National Defence Défense nationale

Canada

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Abstract

Infrared tympanic thermometers (ITT) are used to determine core body temperature in human subjects. Current models are unreliable in non-clinical and non-laboratory situations.

A new ITT device is being developed to correct this problem. To ensure that this device reliably measures the core body temperature, thermal casts of the human ear were created. These casts can accurately mimic and monitor the thermal conditions of the human auditory canal by using heating wire and thermocouples. They are also anatomically accurate and represent the various shapes and sizes of adult ear canals.

It is recommended that new ITT devices should be subjected to testing with these thermal models since the ability to control and monitor the temperature of the casts allows for an accurate analysis.

Résumé

Les thermomètres tympaniques à infrarouge servent à mesurer la température corporelle centrale chez les sujets humains. Les modèles courants ne sont cependant pas fiables hors du contexte de la clinique et du laboratoire.

Pour corriger cette situation, on met actuellement au point un nouveau thermomètre tympanique. Pour s'assurer que l'appareil mesure la température corporelle centrale de façon fiable, on a créé des moulages thermiques d'oreille humaine. Ces moulages permettent de reproduire exactement et de surveiller les conditions thermiques du conduit auditif humain à l'aide d'un fil chauffant et de thermocouples; ils sont également exacts sur le plan anatomique et reproduisent les diverses formes et tailles des conduits auditifs adultes.

On recommande de soumettre les nouveaux thermomètres tympaniques à infrarouge à des essais utilisant ces modèles thermiques étant donné que la capacité de contrôler et de surveiller la température des moulages permet une analyse exacte.

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Executive summary

A method of continuously monitoring core body temperature in extreme condition is required by Search and Rescue and other paramedics in field condition. Most current methods of monitoring the core body temperature are invasive and not suitable for non-clinical and non-laboratory situations. One of the least invasive reliable sites to measure the core body temperature is the tympanic membrane. However, current Infrared Tympanic Thermometer (ITT) devices have proven to be unreliable. In order to correct this problem, a new ITT device is being created. To verify the functionality of this device, thermal casts of the human auditory canal were created.

These casts were created to accurately represent the various sizes and shapes of adult human auditory canals. They were created to mimic the thermal and physical conditions of the auditory canal and were thus required to meet certain conditions. These conditions are:

1. Must be flexible to accurately emulate skin;
2. Must be dark in color to emulate a black body for proper emissivity in the ear canal;
3. Must have a method of measuring its current temperature at various sections to validate measurements acquired from instrument;
4. Must be heated in such a manner that the thermal conditions of the human ear are mimicked.

A dark brown silicon rubber, heating wire and thermocouples are thus used to create these casts. The thermocouples and heating wire are placed so that the proper temperature distributions can be reached and monitored. Six casts were built to simulate the range of anatomical variation in human ear canals.

It is recommended that these casts be used to verify the functionality of the new ITT device. They will allow the device to be tested in various canals of different shapes and sizes and ensure that temperatures read by the device are accurate.

Arsenault, G.A., Ducharme, M.B. 2001. Thermal models of the human auditory canal. DCIEM TR 2001-016. Defence and Civil Institute of Environmental Medicine.

Sommaire

On a besoin d'une méthode permettant de surveiller en continu la température corporelle centrale dans des conditions extrêmes. La plupart des méthodes actuelles de surveillance de la température centrale sont invasives et ne conviennent pas à d'autres contextes que ceux de la clinique ou du laboratoire. L'un des sites fiables les moins invasifs pour mesurer cette température est le tympan de l'oreille. Toutefois, les thermomètres tympaniques à infrarouge actuels s'avèrent non fiables. Pour corriger cette situation, on met actuellement au point un nouveau thermomètre tympanique. Pour vérifier le fonctionnement de ce nouvel instrument, on a créé des moulages thermiques du conduit auditif humain.

Ces moulages ont été créés pour reproduire exactement les différentes tailles et formes du conduit auditif humain de l'adulte; ils ont également été conçus pour reproduire les conditions thermiques et physiques de ce conduit, et devaient donc à ce titre satisfaire aux conditions suivantes :

1. être souples afin d'imiter exactement la peau;
2. être de couleur foncée pour imiter un corps noir et obtenir la bonne émissivité dans le conduit auditif;
3. permettre de mesurer la température courante dans diverses sections afin de valider les mesures obtenues à l'aide de l'instrument;
4. être chauffés de façon à reproduire les conditions thermiques de l'oreille humaine.

On s'est donc servi d'un fil chauffant et de thermocouples en caoutchouc silicone brun foncé pour créer les moulages. Les thermocouples et le fil chauffant sont disposés de façon à permettre d'atteindre les distributions appropriées de la température et de les contrôler. Six moulages ont été construits pour imiter la gamme des variations anatomiques du conduit auditif humain.

On recommande d'utiliser ces moulages pour vérifier le fonctionnement des nouveaux thermomètres tympaniques à infrarouge. Ils permettront de tester les instruments dans divers conduits de tailles et de formes différentes et de vérifier que les températures relevées sont exactes.

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1. Introduction

The Human Performance and Protection (HPP) group aims to develop a non-intrusive instrument to accurately monitor core body temperature, a biomedical signal which is often used as an indicator for physiological stresses and illness. Currently many different methods exist to accurately measure core body temperature in clinical situations. Experts believe that the pulmonary artery is the best site of measurement but this requires the use of a catheter and is only suitable in hospitals. Also used are esophageal probes and rectal probes. However, in non-clinical or non-laboratory situations these methods are not appropriate due to their invasive nature. A device capable of accurately measuring core body temperature in non-clinical situations would be extremely useful to wilderness medical personnel. Such a device could prove very valuable in both military and civilian settings.

Tympanic thermometry has been determined to be one of the least invasive and arguably one of the most reliable (1) method of continuously monitoring the core body temperatures in non-clinical settings. Current models used in clinical situations are not providing accurate and reliable measurements of the tympanic temperature. The auditory canal near the tympanic membrane affects the readings from those instruments. Studies done by Ducharme (3), Hansen (4), Deschamps (2) and the Naval Health Research Center (7) have shown that in non-clinical situations the surrounding environment introduces error into the readings of commercially available infrared tympanic thermometers (ITT).

The main problem with these ITTs is that the shape of the auditory canal is not straight. Figure 1 shows both the anterior and superior views of the auditory canal. The curvature seen in the superior view serves to hide the tympanic membrane from view and since infrared emissions follow the same path as visible light this explains why current ITTs cannot collect emissions exclusively from the tympanic membrane. A new device is under development to correct this problem. The goal of this paper is to outline a method of testing this device using models of the human ear.

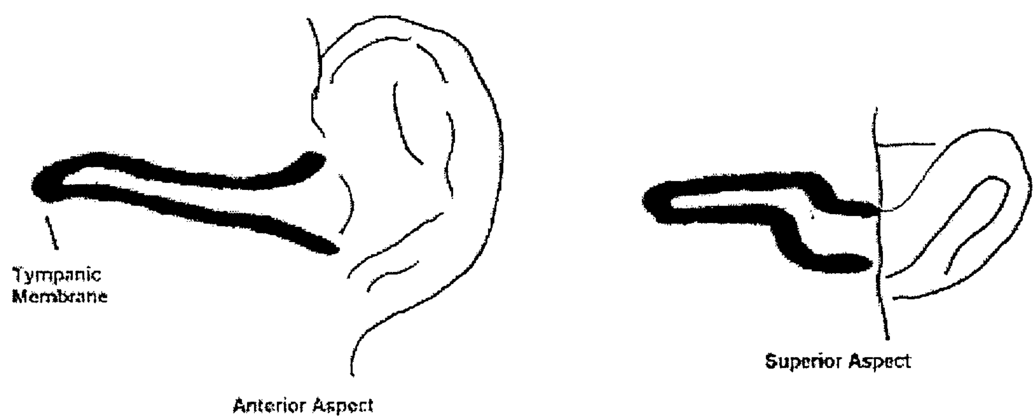

Figure 1 - Anterior and superior view of human ear canal. Reproduced from Pompei, 1996 (6)

2. Ear canal anatomy

To model the human ear canal, a basic understanding of the anatomy of the outer canal is needed. Human ears have a s-shaped canal of various shapes and sizes. Stinson and Lawton (8) performed a study whereby they made complete ear canal molds of male and female adult cadavers of a wide age range. They have shown that the length of the ear canal varies from 27 mm to 35 mm measured along a curved center axis and that the cross-sectional area in the middle portions of the canal range between 25 mm^2 and 70 mm^2 (8). Figure 2 shows various shapes of ear canals. Gray's Anatomy (5) also states that the diameter of the tympanic membrane varies from 8 to 9 mm in its shortest diameter and 9 to 10 mm in its longest diameter.

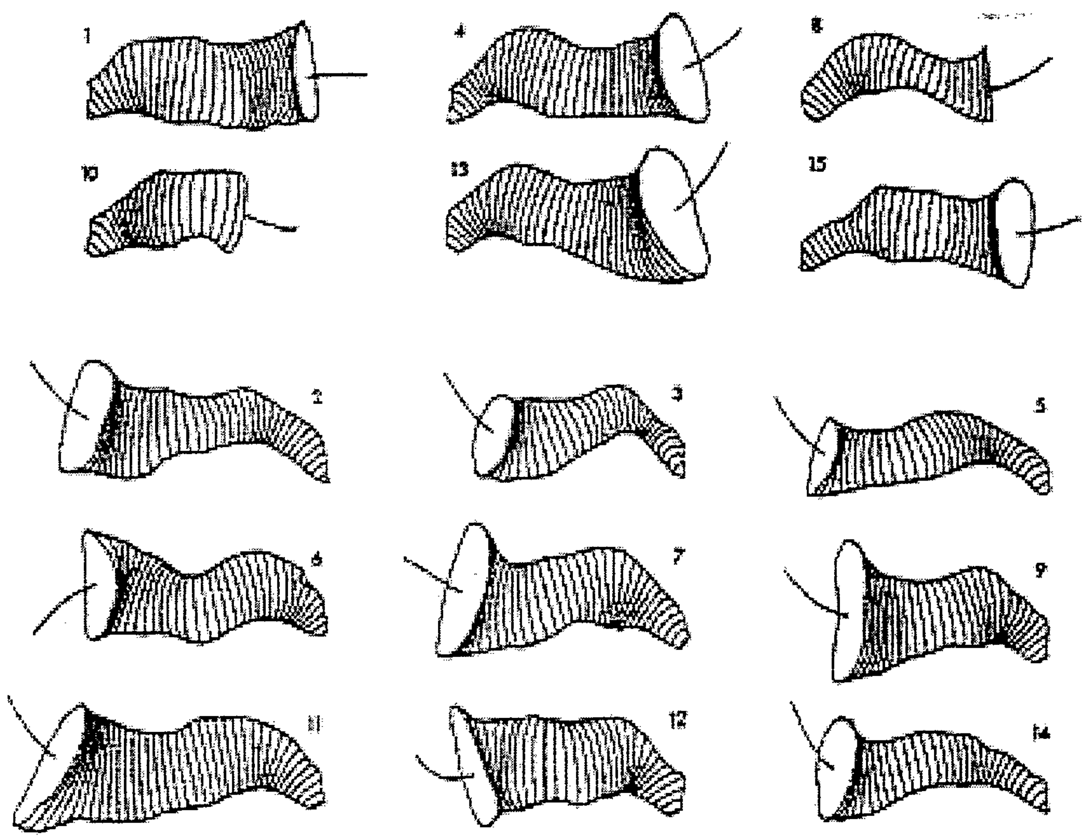

Figure 2 – Different shapes of ear canals from male and female cadavers. Reproduced from Stinson and Lawton, 1989 (8)

It is also important to note that there are two main sections to the ear canal: the optically open section and the optically closed section. The optically open section is in the outer portion of

the ear and is fairly flexible since it is lined by cartilage. The temperature of this section is greatly affected by the environment. The optically closed section is lined by bone and its temperature is relatively close to the tympanic temperature. This is illustrated in Figure 3 and the temperature gradient resulting from this is seen in Figure 4.

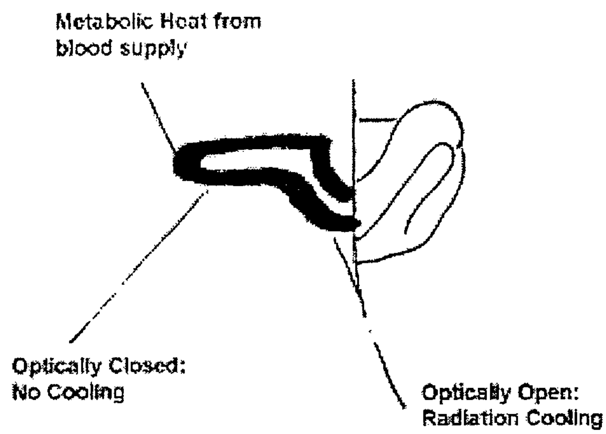

Figure 3 – Heat Transfer to Environment in Ear Canal. Reproduced from Pompei, 1996 (6)

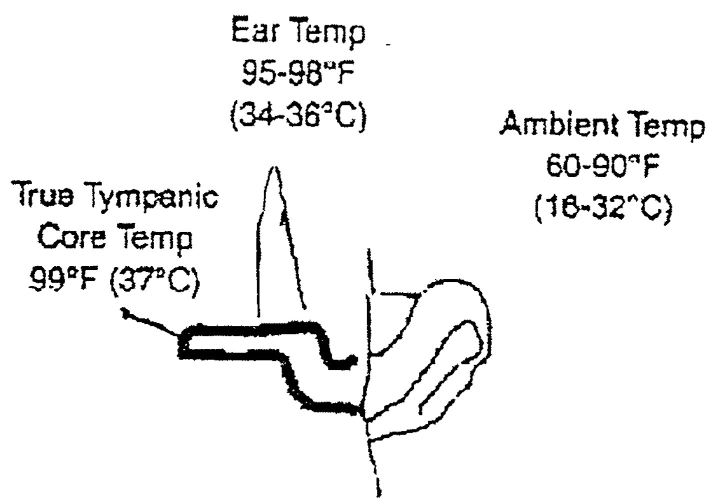

Figure 4 – Temperature Gradient in Ear Canal. Reproduced from Pompei, 1996 (6)

3. Model requirements

The main requirement of the model ears is that they represent all shapes and sizes of possible ear canals in humans. In order to meet this requirement, ear canals molds were acquired from Emsee Laboratories (Toronto, ON), a company which makes hearing aids for patients across Canada. Over two thousand molds from young and old Canadians were examined and a sample of six was carefully selected to represent the various sizes and shapes of canals observed. The only problem with these molds is that current techniques prevent the audiologists from going too deep in the canal. Most molds barely pass the second bend of the canal. For this reason only molds with the second bend clearly evident are chosen and small plaster extensions are created to obtain a more accurate representation of the length of the canal. Discussions with audiologists (9) led to the conclusion that the length of the canal beyond the second bend ranges from 10 mm to 15 mm. Table 1 qualifies the six chosen molds. They are judged by the length of the canal, the diameter of the canal at the tympanic membrane in both their longest and shortest direction, and the general shape of the ear. Both the approximate angle of bend to the nearest 15 Degrees and the size of the canal are used to judge the shape of the ear.

Table 1 – Mold Characteristics

MODEL	GENERAL DESCRIPTION	APPROXIMATE LENGTH (MM)	TYMPANIC LARGE DIAMETER (MM)	TYMPANIC SHORT DIAMETER (MM)
1	45 Degree Bend Regular Size	25	8.8	7.8
2	45 Degree Bend Narrow Canal	24	12	5.5
3	30 Degree Bend Small Canal	20	7.8	5.1
4	45 Degree Bend Regular Size	23	7.9	6.7
5	30 Degree Bend Small Canal	22	8.1	6.3
6	30 Degree Bend Large Canal	26	10.4	7.7

To test the newly developed ITT instrument casts of these molds are needed. The following requirements are used in deciding how the cast is to be constructed:

1. The material of the canal must be flexible to accurately emulate skin;
2. The color of the material must be dark in order to emulate a black body within the ear canal for proper emissivity in the infrared spectrum;
3. A method of measuring the temperature at various sections must be incorporated to validate measurements acquired from the instrument;

4. A method of heating the tympanic membrane and the ear canal must be incorporated to emulate the thermal conditions of the human body.

4. Model construction

In order to properly emulate the human skin, a mold making silicone (model VI-SIL V-1068; Rhodia VSI, Troy, NY) with pigments (brown plastic colorant 61-59410; Ferro Inc., Edison, NJ) was selected. This silicone is a viscous liquid until mixed with a catalyst. When mixed with the catalyst the liquid slowly acquires a rubbery texture capable of emulating skin. The viscosity of the silicone also allows thin coats of silicone to be formed when pored over the mold.

The first step in building the cast is to place thermocouples at various locations in the cast. These thermocouples made of gage 40 copper constantan wire (Omega Engineering, Stamford, CT) were placed just below the surface of the canal. In order to do this, a thin coat of silicone was pored onto the mold and allowed to set. Small holes were then pierced in the silicone and the thermocouples were slipped into the holes. The location of these thermocouples was chosen to ensure that the temperature distribution of the entire ear canal could be measured. Two thermocouples were placed on the tympanic membrane, two were places on the osseous section of the ear canal, two were placed on the cartilaginous section of the ear canal and one was placed on the outer ear. Figure 5 shows the general locale where the thermocouples were placed. A second coat of silicone was then placed over the thermocouples to hold them in place.

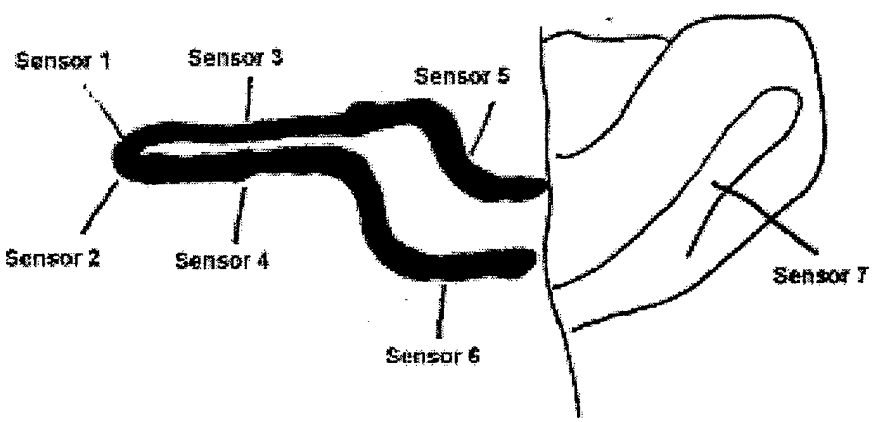

Figure 5 – Thermocouple Locations in the Ear Canal Models

In order to heat the cast, nickel-chromium alloy resistance wire was used (0.18 mm diameter). As discussed in the previous section, there are two main sections in the ear canal; the osseous section and the cartilaginous section. The temperature of the osseous section varies little from the temperature of the tympanic membrane or the core temperature while the temperature of the cartilaginous section demonstrates a significant drop. For this reason three distinct section of resistance wire are used to better model the human ear. A coil is wrapped around the cartilaginous section of the canal, another coil is wrapped around the osseous section of the canal and a grid of wire is placed on the tympanic membrane. Figure 6 shows the heating configuration of the cast.

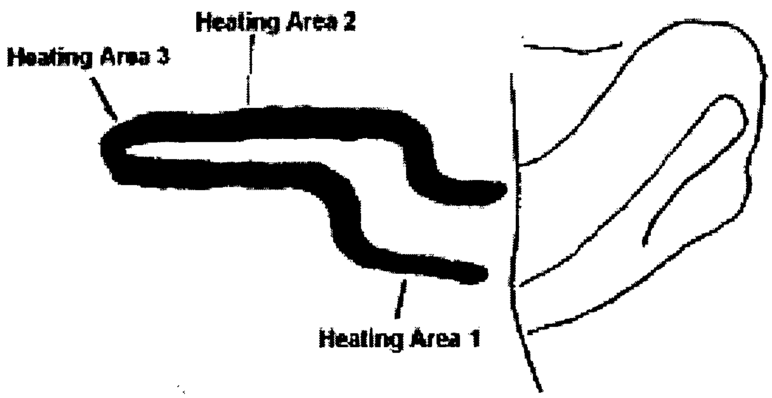

Figure 6 – Heating Configuration in the Ear Canal Models

Once both the thermocouples and the heating wire are placed on the cast, the last step is to dip the entire configuration in a bath of liquid silicone. This creates a firm cast that can be used to test the instrument.

5. Model use

The entire ear model setup consist of three power sources, one thermocouple reader, a switch to designate which thermocouple is being read, a stand to hold the ear model in an upright position and the cast of the ear. Each power sources will be connected to the heating wires of a particular region in the ear canal while the switch will be connected to both the thermocouples of the cast and the thermocouple reader. The cast should be placed in the holder such that the entrance to the ear canal is at the bottom. Figure 7 illustrates this setup.

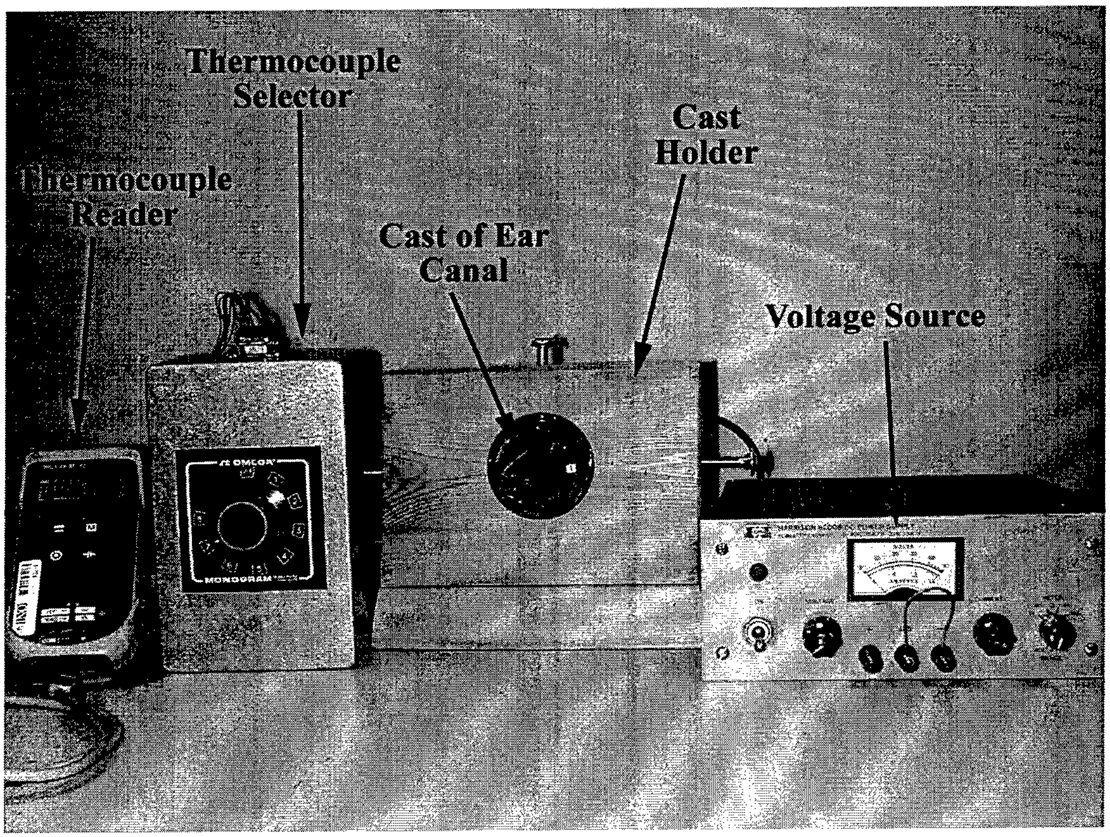

Figure 7 – ITT testing setup, with the cast in its support.

In order to test an ITT instrument, one should preheat the casts for approximately two hours. The tables in Appendix A show the approximate voltages required to acquire specific temperatures in various regions of the canal while the cast is used at an ambient temperature of 25.5 °C. The maximum current used to heat the cast was less than 0.1 A. To test the ITT instrument, simply insert the instrument into the canal and compare its reading to the thermocouple readings located at the tympanic membrane.

6. Conclusions and recommendations

The thermal models developed to test an ITT device under development should be used to validate measurements acquired. They will ensure that the device is functional in various canals of different sizes and shapes and will not be hampered by thermal noise from areas in the canal other than the tympanic membrane.

7. References

1. Brinnel, H and Cabanac, M. Tympanic Temperature is a Core Temperature in Humans. J. Therm. Biol., 14(1): 47-53, 1989.

2. Deschamps A., Levy, R.D., Cosio, M.G., Marliss, E.B., S. Magder. "Tympanic Temperature Should Not be Used to Assess Exercise Induced Hyperthermia". Clin. J. Sport Med., 2(1): 27-32, 1992.

3. Ducharme M.D. et al. "Evaluation of Infrared Tympanic Thermometers during Normothermia and Hypothermia in Humans". Thermoregulation. Annals of the New York Academy of Sciences, 813: 225-229, 1997.

4. Hansen, R.D., Olds, T.S., Richards, D.A., Richards, C.R., Leelarthaepin, B. "Infrared Thermometry in the Diagnosis and Treatment of Heat Exhaustion" Int. J. Sports Med. 17, 66-70, 1996

5. Davies, D.V., Coupland, R.E. Gray's Anatomy, Thirty-Fourth Edition. Longmans, Green and Co. London. 1969.

6. Pompei, M. and Pompei F. Physicians reference handbook on temperature. Exergen Corporation, Watertown, 1996.

7. Sopchick T.L., Trone, D.W., Pozos, R.S. "Evaluation of Infrared Thermometry of Tympanic Cavity as an Indicator of Core Temperature". Report No. 94-3. Naval Health Research Center, San Diego, CA, 1994.

8. Stinson M. R, and B.W. Lawton. "Specification of the geometry of the human ear canal for the prediction of sound-pressure level distribution". J. Acoust. Soc. Am., 85(6): 2492-2503, 1989.

9. Storms, D. and Moodie, S. Mt Sinai Hospital. Toronto. Oct 2000. (personal communication).

Appendix A: Voltage requirement for the models

Model 1									
Heating Wire Voltage			Thermocouple Temperature						
1	2	3	1	2	3	4	5	6	7
0	1	3	27.1	27.1	26.7	26.7	26.4	26.4	26.3
0	1	4	29.2	29.1	28.1	28.1	27.4	27.4	27.2
0	1	5	31.7	31.5	29.2	29.1	27.7	27.7	27.4
0	1	6	35	34.8	31.1	30.8	28.9	28.8	28.2
0	1	7	37.4	37.3	32.1	31.7	29.2	29.2	29.1
0	1	8	39.9	39.6	33.2	32.7	29.6	29.6	28.7
3	3	3	29.7	29.7	29.4	29.5	29.1	28.8	28.1
3	3	4	31.1	31.1	30.1	30.1	29.4	29.2	28.4
3	3	5	33	32.9	31	30.9	29.8	29.6	28.6
3	3	6	35.2	35	32	31.8	30.2	30	28.8
3	3	7	37.8	37.7	33.1	33	30.6	30.5	29
3	4	7	38	37.8	33.8	33.7	30.8	30.6	29
3	5	7	38.3	38.4	34.8	34.5	31.2	30.8	29.2
3	6	7	38.9	38.8	35.9	35.6	31.7	31.3	29.5
3	4	8	41.4	41.2	35.7	35.4	32.1	32	30.1
3	5	8	41.8	41.7	36.7	36.3	32.3	32	30.1
3	6	8	41.8	42.1	37.3	37	32.5	32	30

Model 2										
Heating Wire Voltage			Thermocouple Temperature							
1	2	3	1	2	3	4	5	6	7
0	1	3	27	27			26.4	26.3	26.3
0	1	4	28.8	28.8			27.4	27.3	27
0	1	5	31.2	31.7			27.8	27.3	27.1
0	1	6	34	34.8			28.8	28.2	27.7
0	1	7	36.2	37.1			29.2	28.5	27.9
0	1	8	38.3	39.6			29.6	28.7	28.1
3	3	3	29.6	29.6			29.5	28.9	28.1
3	3	4	30.9	31			29.8	29.2	28.3
3	3	5	32.5	32.7			30.1	29.3	28.3
3	3	6	34.6	35.2			30.7	29.8	28.7
3	3	7	36.9	37.5			31	29.8	28.4
3	4	7	37	37.8			31.1	29.8	28.5
3	5	7	37.5	38.4			31.8	30.2	28.7
3	6	7	38.3	38.3			32.4	30.6	28.9
3	4	8	40.1	41.3			32.4	30.9	29.3
3	5	8	40.7	41.8			32.8	31.1	29.4
3	6	8	41.2	42.1			33.2	31.1	29.3

Model 3									
Heating Wire Voltage			Thermocouple Temperature						
1	2	3	1	2	3	4	5	6	7
0	1	3	26.9	26.9	26.5	26.5	26.3	26.2	
0	1	4	28.8	28.7	27.7	27.7	27.1	27	
0	1	5	31.8	31.7	28.7	28.7	27.4	27.3	
0	1	6	34.6	34.6	30.1	30.2	28.2	28	
0	1	7	37.1	37.1	31	31.3	28.3	28.2	
0	1	8	40	39.9	32	32.5	28.8	28.5	
3	3	3	30.1	30.1	29.9	29.9	29.7	29	
3	3	4	31.8	31.5	30.4	30.4	30	29.3	
3	3	5	33.4	33.2	31.1	31.1	30.2	29.4	
3	3	6	35.6	35.5	32	32.2	30.6	29.8	
3	3	7	38.2	37.9	32.5	32.5	30.5	29.5	
3	4	7	37.9	37.9	33.3	33.3	30.6	29.6	
3	5	7	39.1	39.1	35	35.2	31.2	30.2	
3	6	7	40	40	36.6	36.7	31.6	30.5	
3	4	8	41.8	41.8	35.1	35.1	31.7	30.7	
3	5	8	42.7	42.6	36.7	36.7	32.1	31	
3	6	8	43.3	43.2	38	38	32.2	31.3	

Model 4									
Heating Wire Voltage			Thermocouple Temperature						
1	2	3	1	2	3	4	5	6	7
0	1	3	27.2	27.2	26.7		26.3	26.3	
0	1	4	29.5	29.5	28.1		27.3	27.3	
0	1	5	32.9	33.2	29.3		27.6	27.6	
0	1	6	36.3	36.7	31.1		28.6	28.8	
0	1	7	39.3	40.3	33.2		29	29.1	
0	1	8	42.6	43.7	33.4		29.4	29.6	
3	3	3	30.6	30.7	30.4		29.7	29.6	
3	3	4	32.4	32.6	31.2		30.1	30	
3	3	5	35.3	35.4	32		30.4	30.3	
3	3	6	37.3	37.8	33.3		31	31	
3	3	7	39.8	40.7	34.1		31.1	31.1	
3	4	7	40.3	41.1	35		31.2	31.2	
3	5	7	41.3	42.2	36.5		31.7	31.7	
3	6	7	42.5	43.1	38.5		32.4	32.4	
3	4	8	44.7	45.6	37		32.3	32.3	
3	5	8	45.5	46.4	38.3		32.6	32.6	
3	6	8	46.7	47.4	39.2		32.7	32.8	

Model 5									
Heating Wire Voltage			Thermocouple Temperature						
1	2	3	1	2	3	4	5	6	7
0	1	3	27	27.1	26.9	26.8	26.6		26.5
0	1	4	29	29	28.3	28.2	27.4		27.2
0	1	5	32.2	32.5	30	29.7	27.9		27.5
0	1	6	35.1	35.5	32	31.4	28.8		28.2
0	1	7	37.7	38.2	33.4	32.7	29.3		28.5
0	1	8	40.6	41.9	35	34.1	29.7		28.8
3	3	3	31.2	32.5	31.6	31.4	30		28.8
3	3	4	32.9	33.2	32.5	32.2	30.3		29.2
3	3	5	34.8	35.3	33.6	33.3	30.8		29.4
3	3	6	37.4	37.8	35.2	35	31.5		30
3	3	7	39.8	40.5	36.5	35.8	31.8		30
3	4	7	40.7	41.5	37.8	37.1	32.1		30.1
3	5	7	42	43.2	39.7	39.2	32.5		30.2
3	6	7	43.9	45.2	42.6	42.1	33.5		30.8
3	4	8	44	45	39.8	39	32.7		30.5
3	5	8	45.4	46.8	41.8	41.1	33.3		30.8
3	6	8	46.9	48.3	44.1	43.4	33.8		31.1

Model 6									
Heating Wire Voltage			Thermocouple Temperature						
1	2	3	1	2	3	4	5	6	7
0	1	3	26.8	26.7	26.5		26.3		
0	1	4	29	28.3	27.5		26.9		
0	1	5	31.3	30.2	28.8		27.2		
0	1	6	33.8	32.3	30.1		27.8		
0	1	7	36.1	34.1	31.1		27.9		
0	1	8	38.7	36.1	32		28.1		
3	3	3	33.4	29	28.8		28.7		
3	3	4	33.9	30.2	29.6		29.5		
3	3	5	34.7	31.6	30.5		29.3		
3	3	6	35.8	33.6	31.7		29.6		
3	3	7	36.5	34.6	32.1		29.3		
3	4	7	36.7	34.8	32.5		29.3		
3	5	7	37.5	35.6	33.4		29.7		
3	6	7	37.9	36.3	34.1		29.7		
3	4	8	39.8	37.3	33.8		29.5		
3	5	8	40.2	37.9	34.3		29.7		
3	6	8	40.4	38.2	35		29.8		

Note: Empty columns indicate damaged sensor.

DOCUMENT CONTROL DATA SHEET

1a. PERFORMING AGENCY DCIEM	2. SECURITY CLASSIFICATION UNCLASSIFIED -
1b. PUBLISHING AGENCY DCIEM	

3. TITLE

(U) Thermal models of the human auditory canal

4. AUTHORS

Ghislain A. Arsenault, Michel B. Ducharme

5. DATE OF PUBLICATION January 11 , 2001	6. NO. OF PAGES 24

7. DESCRIPTIVE NOTES

8. SPONSORING/MONITORING/CONTRACTING/TASKING AGENCY

Sponsoring Agency:
Monitoring Agency:
Contracting Agency :
Tasking Agency:

9. ORIGINATORS DOCUMENT NO. Technical Report 2001-016	10. CONTRACT GRANT AND/OR PROJECT NO. 6cg	11. OTHER DOCUMENT NOS.

12. DOCUMENT RELEASABILITY

Unlimited distribution

13. DOCUMENT ANNOUNCEMENT

Unlimited

14. ABSTRACT

(U) Infrared tympanic thermometers (ITT) are used to determine core body temperature in human subjects. Current models are unreliable in non-clinical and non-laboratory situations.

A new ITT device is being developed to correct this problem. To ensure that this device reliably measures the core body temperature, thermal casts of the human ear were created. These casts can accurately mimic and monitor the thermal conditions of the human auditory canal by using heating wire and thermocouples. They are also anatomically accurate and represent the various shapes and sizes of adult ear canals.

It is recommended that new ITT devices should be subjected to testing with these thermal models since the ability to control and monitor the temperature of the casts allows for an accurate analysis.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) ear canal, tympanic membrane, core temperature, infrared thermometer

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